

Visual Functioning of Aviation Maintenance Inspectors

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Background: While an FAA vision standard does not exist for aviation maintenance inspectors, guidance has been given for vision recommendations for NDI/NDT inspectors. This study measured the vision functioning of 150 volunteer inspectors to determine if inspectors' vision complies with the recommended vision standards and met the occupational demands of aircraft maintenance inspections. **Methods:** Vision tests were performed on NDI/NDT and visual inspectors at 2 aircraft maintenance facilities. The results were compiled and compared to the recommended vision standards for NDI/NDT personnel. **Results:** Mean age of inspectors was found to be 44.7 years. Mean visual acuity of inspectors was 20/16.6 and 20/16.8 at 16 foot and 16 inch test distances, respectively. All inspectors met the present distance VA recommendations and only one failed to meet the present recommendation for near vision. **Conclusions:** Aircraft maintenance inspectors have excellent vision functioning. This indicates that medical personnel at these maintenance facilities are adequately screening employees. In spite of these excellent results, inspectors should be educated on the limitations of focusing that accompanies aging and provided with various focusing devices to allow clear and comfortable vision at all required viewing distances and directions.

INTRODUCTION

Inspection tasks for aircraft maintenance inspectors are visually demanding. Whether personnel conduct inspections using only a flashlight, a simple magnifier, or sophisticated NDI/NDT equipment, visual identification is the primary method used to find cracks and other defects which affect the integrity of an aircraft or aircraft component. The National Transportation Safety Board (NTSB) has identified the failure by inspectors to detect visible corrosion, cracks, or inclusions as a causative factor of several aviation accidents (NTSB, 1998, 1990, 1989).

In spite of the importance of vision to the inspection process, the Federal Aviation Administration (FAA) had not required maintenance inspectors to meet occupational vision standards. The FAA's Production and Airworthiness Division (AIR-200) recognized this lack of national policy and prepared a memorandum (Production and Airworthiness Division, 2001), dated September 26, 2001, to address the issue. This memorandum follows an FAA advisory circular from February 1999 that addressed the same topic (FAA, 1999). Several national and international organizations have put forth recommendations for qualifications of NDI/NDT personnel that include initial and recurrent training, levels of competence, and minimum vision standards and test intervals. The September 2001 FAA memorandum identified the

standards thought to be acceptable for assuring that only qualified individuals perform NDI/NDT inspections and procedures:

- 1) MIL-STD-410E, Military Standard
- 2) ATA Specification 105, Air Transport Association
- 3) AIA-NAS-410, Aerospace Industries Association
- 4) ISO 9712, International Standards Organization

The memorandum further describes the generic elements of the different standards and states minimal requirements that organizations developing NDI/NDT qualification programs should meet. In terms of vision testing, the memorandum is summarized below:

1. Vision Examinations: NDT personnel should receive documented vision and color blindness testing at reasonable intervals (one to two years, shorter preferred). Vision examinations shall be administered by personnel in accordance with the standard to determine qualification.

(a) Near Distance Vision Requirements:

Natural or corrected near distance acuity in at least one eye capable of reading the Jaeger #1 Test Chart or equivalent at a distance of not less than 30 cm.

(b) Color Vision Requirements:

Ability to differentiate among colors used in NDT method(s).

These vision guidelines are specifically written for NDI/NDT personnel and lack the specificity required to ensure uniformity of compliance throughout the industry. No such guidelines exist for visual inspectors. Because of the intimacy between the two inspection classifications (i.e., visual inspection vs. NDI/NDT), however, most maintenance facilities use similar testing requirements for both types of inspectors.

In terms of visual acuity, the ATA Specification 105 standard includes a distant visual acuity measure, albeit lenient (20/50), while the AIA-NAS-410 and FAA guidance memorandum do not. In addition, other vision requirements set forth in various industry programs are not uniform. The training manual for NDI/NDT personnel for one national airline lists visual acuity requirements at nearpoint of 20/25 in at least one eye and at distance of 20/30. At another airline, the requirements are more rigorous with a nearpoint requirement of 20/20 and a distance requirement of 20/25. Additionally, the question of an intermediate distance visual acuity requirement is not addressed within any of the aforementioned documents, even though inspectors performing NDI/NDT procedures frequently use working distances between 16 and 80 inches.

In this study, the on-the-job visual capabilities of 150 representative visual and NDI/NDT inspectors were measured. The intent was to determine the visual status of a representative group of inspectors to predict what effect, if any, a change in the present vision standards would have on the present workforce. It is also hoped that visual and medical information obtained can help determine if the present recommendation for the frequency of vision assessment (i.e., not greater than every 2 years) is adequate to ensure a visually competent workforce. The results could also be used to determine whether the present medical surveillance programs employed at the subject facilities are adequately ensuring that inspectors meet the current vision guidelines.

METHODS

The research protocol was approved by the Institutional Review Board of the Ohio State University. Vision screening was performed at two aircraft maintenance facilities. Facility #1 was a private maintenance facility, while facility #2 was

a national airline. Various vision measures were taken on 150 volunteer visual and NDI/NDT inspectors (59 at facility #1 and 91 at facility #2). After a short visual and medical history that included documentation of age, experience as an inspector, and whether vision care insurance was present, subjects underwent the following visual tests with their current corrections (if appropriate):

- a) **Distance Visual Acuity in each eye (LogMAR chart),**
- b) Distance Binocular Low Contrast Visual Acuity (Bailey-Lovie Chart),
- c) Binocular Visual Acuity at 32 inches,
- d) Binocular Visual Acuity at 16 inches,
- e) Global and Local Nearpoint Stereoacuity,
- f) Color Vision (Ishihara Pseudoisochromatic Plates (PIP) and Farnsworth D-15 for PIP failures),
- g) Nearpoint Contrast Sensitivity (Pelli- Robson Chart), and
- h) Intraocular Pressure (Tonopen).

An objective measure of refractive error was also taken (i.e., autorefractor); however, the results of that testing are not reported here. Additionally, the powers of the current spectacles were measured and lens designs were recorded (i.e., normal bifocal, multifocal, occupational bifocal, or single vision lenses). Measures of vision were taken by experienced eyecare personnel from The Ohio State University College of Optometry and the Vision Research Team of the Civil Aerospace Medical Institute (CAMI) from the FAA in Oklahoma City, Oklahoma.

RESULTS

The results of the screening are presented in the appropriate sections below and are divided into classes for the different types of inspections (i.e., visual vs. NDI/NDT). A summary of these results are presented in Table 1.

Inspector Demographics.

Inspector Age. The mean age of these 150 inspectors is 44.6 years \pm 7.9 years. The ages did not differ significantly between examination sites (Two Sample T, t-value = -0.93, p = 0.357). The age of visual and NDI/NDT inspectors were documented in an associated study (Good et al., 2004) for 183 inspectors from 5 maintenance facilities. One of those facilities was Facility #1 from the present study. Therefore, only the ages of inspectors from facility #2 were compared to the

previously surveyed population. The ages of these populations also did not differ significantly (Two Sample T, t-value = -0.89, p = 0.375). Therefore, the two populations were combined to give an age value representative of the overall inspector population. The figures for the combined population (n = 274) are:

Mean Age = 44.8 ± 8.4 years,
Range 25 to 68 years.

Systemic and Ocular Disease. Only 6 inspectors, or 4% of our subject population, reported having diabetes. This is less than the reported 8.7% of the US population over 20 years of age with diabetes (Cowie et al., 2004). Twenty-seven participants (18% of our subjects) reported having high blood pressure. Estimates in the United States are that 31.3% of adults have high blood pressure (Fields et al., 2004). Using these systemic conditions as overall health indicators, one could infer that the subject population was more healthy than the US population as a whole.

Only 2 subjects (1.3%) reported being treated for glaucoma. National estimates are that 1.9% of the over 40 population has glaucoma (Prevent Blindness America / National Eye Institute, 2002). As many of the participants were under 40 (26.7%) and the prevalence of glaucoma increases with age, it was not possible to compare our figures to the over 40 national estimate.

Experience and Classification of Inspection. Study participants were classified as either visual or NDI/NDT inspectors based upon which activity occupied the majority of their work time. Fifty of the participants reported that NDI/NDT inspections accounted for more than 50% of their workdays (33.8% classified as NDI/NDT inspectors), while 98 reported less than 50% (66.2% classified as visual inspectors). Two participants reported an equal, 50/50 split of work activities. Data from facility #2 were then combined with the previously reported survey data (Good et al., 2004). The number of years of aviation inspection experience for surveyed inspectors did not differ significantly between inspector classification (visual versus NDI/NDT, t-value = 0.21, p = 0.836) in spite of visual inspectors being slightly older (mean age 45.7 years [visual] to 43.3 years [NDI/NDT], t-value = 2.02, p = 0.045). The inspector experience for the combined populations (n = 274) is:

Mean Years as Inspector = 10.3 ± 7.7 years,
Range: < 1 year to 42 years.

Table 1
Screening Results
Mean \pm SD

Inspector Age	
Facility #1	45.3 ± 7.2 years
Facility #2	44.1 ± 8.3 years
Overall	44.6 ± 7.9 years
Visual Acuity (with correction)	
(Log MAR, 20/20 = 0.0)	
16 ft. (better eye)	-0.08 ± 0.08 (20/16.6)
32 in (binocular)	-0.17 ± 0.09 (20/13.4)
16 in (binocular)	-0.08 ± 0.05 (20/16.8)
Contrast Sensitivity	
Low Contrast VA (16 ft)	
LogMAR	0.03 ± 0.09 (20/23.2)
Pelli-Robson (1 m)	1.93 ± 0.05
Stereopsis (seconds of arc)	
Global	255.0 ± 45.5
Local	33.2 ± 35.1
Intraocular Pressure	
Tonopen	13.7 ± 3.3 mm Hg
Color Vision (% Failed)	
Ishihara PIP	3.3%
Farnsworth D-15	2.0%

Visual Measures.

Visual Acuity. Visual acuity measures were taken with correction (if normally worn by the inspector) for each eye at 16 feet (distance), while acuity for near (16 inches) and intermediate (32 inches) distances was measured binocularly. At distance, the mean visual acuity of the better eye was better than 20/16.6; and, only 9 of the 150 inspectors had less than 20/20 with none measuring worse than the 20/50 specified by the ATA specification 105 recommendation. At nearpoint the mean visual acuity was 20/16.8. Eleven individuals scored less than 20/20, but only 1 failed (by a single letter) to meet the 20/25 ATA recommendation. Although ATA specification 105 does not specify an intermediate visual acuity requirement, visual acuity at 32 inches was found to be outstanding (mean acuity = 20/13.4). Only 5 individuals failed to see 20/20 at the intermediate distance.

Contrast Sensitivity. Pelli-Robson contrast sensitivity measures were excellent for these inspectors. Only a single inspector had contrast sensitivity below 1.80. The mean contrast sensitivity was 1.93 (contrast threshold = 1.17%). Low contrast visual acuity (LCVA) is a test, which incorporates elements of both contrast sensitivity and visual acuity. It is often claimed to be a better

indicator than high contrast visual acuity of “real-world” performance. Of the 150 inspectors, 145 had LCVA measured at distance of 20/32 or better. The mean LCVA was 20/23.2.

Stereoacuity. Nearpoint stereoacuity was measured using the Randot Stereo Test. Measures of both local and global stereopsis were made. For local stereopsis a median value of 20” of arc was found (mean = 33.2” of arc). This is the limiting value for the test. Only 2 of the 150 inspectors had worse than 70” of arc on this test. For global stereopsis only 1 inspector was unable to identify any target and only 4 additional inspectors measured less than the best possible.

Color Vision. Five of the 150 inspectors (3.3%) were found to have abnormal color vision by failing the Ishihara PIP test. Of these five, three showed a moderate to severe color vision defect by failing the Farnsworth D-15 test.

Intraocular Pressure. Intraocular pressure (IOP) was measured using the Tonopen tonometer. Mean intraocular pressure as 13.7 mm Hg. Only one inspector was found with IOP measures above 21 mm Hg.

Refractive Correction. For the 150 inspectors, eighty-nine wore some type of spectacles. Sixty-six required a special correction for near activities (see Figure 1). Of these, 25 were single-vision near glasses, 32 were no-line, progressive bifocals, and only 9 were traditional straight-top, line bifocals. None of these workers wore special design, occupational multifocals with a near focusing segment across the top of the lenses.

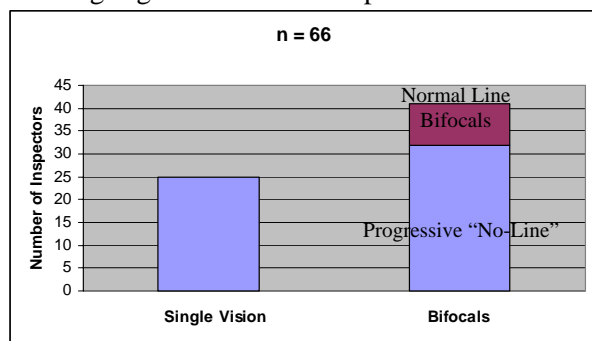


Figure 1. Design of Nearpoint Spectacles

DISCUSSION

In terms of overall systemic and ocular health, the inspectors participating in this study appear to be healthier as a group than the overall US population. As the job duties of most inspectors require a good deal of physical exertion, it is not unreasonable to assume that their active workdays are positive factors in this finding.

The visual functioning of the 150 inspectors examined in this study was also excellent. Only 9 inspectors had less than 20/20 visual acuity at distance with the better eye, and none failed to meet the 20/50 ATA specification 105 distance visual acuity recommendation. At nearpoint, only 11 inspectors had less than 20/20 visual acuity and only 1 did not meet the 20/25 requirement, and this was by just a single letter.

These inspectors also demonstrated excellent visual acuity at the intermediate distance. This was expected for those inspectors at 45 years of age or less. Although near focusing ability decreases with age, those 45 and younger should be able to focus for short periods to near 16 inches from the eyes. For the inspectors older than 45, reading glasses or bifocals become a requirement to focus near objects; and, stronger bifocals can focus for very near objects but leave individuals a focusing “dead-zone” at intermediate distances, where details are blurry through both the distance and bifocal portions of glasses. Individuals older than 50 years must allow for this in the design of their glasses when objects at intermediate distances are viewed. The FAA recognizes this eventuality by requiring pilots with Class I and II medical certificates to demonstrate relatively sharp visual acuity at 32 inches (Nakagawara and Wood, 1998).

The older inspectors in this study were able to see clearly at intermediate distances largely from having progressive addition (i.e., no-line) bifocals. The powers in progressive lenses gradually change from the top to the bottom portions for the lenses allowing clear focusing at intermediate distances. Seventy-eight percent of the bifocal wearers in this study used progressive addition lenses. Of concern, however, is focusing on objects positioned off to the side or superiorly in the field of view. This is often the case for visual inspectors. It becomes difficult to position the head to see through the inferiorly placed bifocal segment when the object of interest is off to one side or above the head. Special care must be taken in the design of eyewear to ensure clear, comfortable vision for these positions.

Inspectors should discuss spectacle design options with their eyecare providers. Clip-on near focusing lenses, occupational bifocals, and special designed lenses to be used solely for inspection tasks are 3 lens alternatives that can provide in focus imagery for all distances and directions required during inspection tasks.

In conclusion, inspectors at the two facilities where testing was conducted appear to have adequate vision function to effectively perform their responsibilities. However, since the subject selection process was entirely voluntary, results could vary for the inspector population as a whole. Proper vision testing at appropriate intervals is the key to maintaining a visually healthy workforce. The addition of an age-related intermediate visual acuity requirement and guidance for selection of appropriate refractive correction would provide additional safeguards to ensure that inspectors retain optimal vision performance as they age.

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